THE VEGETATION OF THE SELKIRKS[1]

CHARLES HUGH SHAW

(WITH MAP)

A most attractive region for the study of mountain vegetation is found in the vicinity of the Continental Divide in Western Canada. The mountains, glacier crowned and of the noblest order, are covered in their lower reaches by luxuriant forests. In the higher altitudes are extensive areas where a rich alpine vegetation finds its appropriate home. The region, therefore, is a most attractive field for the botanist, especially since the whole area is as yet practically undisturbed by man. During the last few years the writer has had considerable opportunity for observation there. Base camps have been established at spots thought favorable for the study of the plant life, and quasi-exploring expeditions have been made into districts remote from the railroad. Although only very moderate progress has been made toward a solution of the great questions which present themselves, it was thought that a description of the vegetation as it exists would be of some interest and of value as a record.

[1] This paper has been compiled from Dr. SHAW'S notes by one of his students (Miss CAROLINE S. ROMER) who accompanied him on three of his six exploring trips in the Selkirks and who studied the vegetation of the region under his guidance during two of these trips.

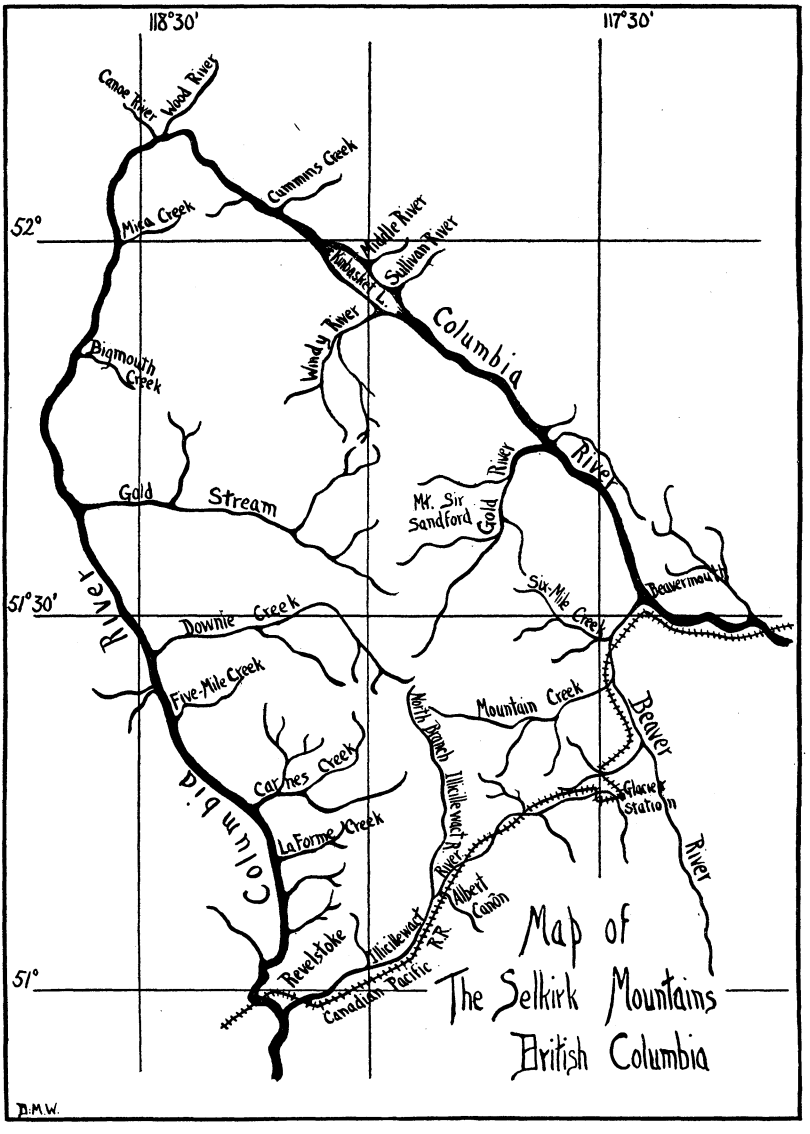
As will be remembered by those botanists who are interested in the development of ecological botany in North America, Dr. SHAW, one of the most earnest and most promising of the younger ecologists, chose as his field of investigation the ecological problems presented by the vegetation of the little known Selkirk Mountains. His work was cut short by his lamentable death by drowning in Kinbasket Lake in July 1910. Extensive notes which he had made during June and July 1910 were unfortunately lost with him. The material that he left comprises, besides many specimens sent to several of the more important herbaria, the introduction to this paper in its present form, and numerous notes concerning the plant life of the Selkirks. To interpret these notes has been no light task. There are doubtless mistakes, errors in interpretation, but, as it seemed to Dr. SHAW'S friends and to his fellow-botanists that his work should not be entirely lost, this record of his Selkirk studies has been made as nearly as possible like the record that he expected to make.

Topography

The general topography of the region will be understood by keeping in mind the course of the Columbia River. The first 500 miles or so of its course are in the form of a huge acute angle whose apex is directed northwest and whose western arm extends southward. The upper or eastern arm flows northwest parallel to the Continental Divide, and the "bend" is just above 52° north latitude. The mountains east of the river and forming the Divide are the Rockies proper; those nearly surrounded by the Columbia, especially those above 51°, are called the Selkirks; while west of the river, and separating its basin from that of Fraser, is the Gold Range. It will thus be seen that the Columbia River rises in the midst of the continental mass of mountains, in the midst also of the cordilleran forest which at this latitude extends from the Great Plains to the dry interior of British Columbia. The area dealt with in the present paper is that of the Selkirks proper, taking 51° north latitude as an arbitrary southern limit; the rest of the boundary being formed, of course, by the river itself. The area thus delimited is practically untouched by human influences. The Canadian Pacific Railway indeed passes through it, and has opened up some wonderful spots to the traveler, but in most places the influence of the railroad has not made itself felt a gunshot from the tracks. North of the railroad there is neither wagon road nor village, store nor post-office, white woman nor child. A scattered line of settlements along the railroad, half a dozen or less inhabited cabins on the river, a mining camp or two, and a few wandering trappers or prospectors constitute the sum of its human influences. From the naturalist's standpoint these have no importance in relation to the broad leagues of wilderness. The phenomena of plant life which may now be seen represent, therefore, the results of conditions operating through a long series of generations, beginning with the last retreat of the ice.

The entire area is extremely mountainous, and in the character of its topography young. The mountains are lofty and precipitous, the streams narrow and swift. Innumerable snowfields and glaciers cover the high summits, tongues of ice not seldom reaching down into the forest. A certain roundness of contour of the lower

mountains contrasts sharply with the more jagged character of the Rockies, but the higher peaks are of the boldest. Although in



absolute altitude the Selkirks are surpassed by many ranges, in elevation of the summits above the valleys they are not easily

equaled. The river and its large tributaries are at altitudes of from 500 m. to nearly 1000 m. The peaks range from 2500 m. to nearly 4000 m. Mountain flanks with a rise of 1000 m. are common, and in certain cases a difference of as much as 2600 m. of altitude occurs within a horizontal distance of two or three miles. Needless to say, such a mountain side presents the most varied forms of vegetation, from tangled forests below to the dwarfed plants of the cold deserts above.

In obtaining an idea of the surface features of the country, it will be helpful to keep in mind again the course of the Columbia. The lakes in which it rises, as well as the first 100 miles of its course, lie in a broad and terraced valley, evidently the site of an ancient lake. Near Donald the river turns abruptly out of this valley into a narrow canyon, and from that point it completes its bend in a series of wild gorges, alternating occasionally with wider and more level valleys. Most interesting problems of captured drainage and reversed flow here await investigation. At one point some 30 miles above the bend, the river expands into Kinbasket Lake. The course of the smaller streams will be apparent from the map. For the most part they descend swiftly as torrents, but in a few places, notably on the Beaver, Downie, and Goldstream, there are portions that have been nearly base-leveled, and in these the activity of the beavers has given rise to extensive swamps.

Climate

Adequate meteorological records have never been made, but the following may give some idea of climatic conditions.

TEMPERATURE.—This factor varies greatly, of course, in connection with altitude, exposure, etc. At the level of the river, summer temperatures of 33° C. are by no means rare, and once I recorded 38° C. At high altitudes, as is usual, temperatures are always low except at noonday in the direct sunlight.

In the season of 1908 two thermographic records were made on Mount Plainside near Beavermouth on the same hillside and exposure, at altitudes of 800 and 1700 m. respectively. The lower station was about 100 m. above the river level; the upper,

in the midst of the subalpine zone.[2] From these records it is evident that less daily variation occurs at high altitudes. The daily maxima are notably less than those at lower altitudes, the nightly minima only slightly so. This accords well with the general observations of meteorologists.

From records kept at Revelstoke throughout the year, it is possible to gain some idea of the temperature during the winter. The minimum of $-50°$ C., while striking, is probably without significance for vegetation. At higher altitudes, owing to inversion of temperature, the cold is probably much less severe. A registering thermometer was left over the winter of 1908–1909 on the top of Mount Grizzly (3000 m.). When found the following summer, it had every appearance of being in good working order and the recorded minimum was $-1°$ F. Of course, the rocks where the instrument was secured were deeply covered with snow during most of the year.

Occasional frosts occur even at river level in midsummer. Thus, on the night of July 20, 1905, there was a heavy frost in the valley of Goldstream (616 m.). I was unable to learn whether there was frost on the mountain flanks a little higher up or not, but suspect that the low temperature prevailed only in the floor of the valley (a case of temperature inversion).

At and above timber line snow may fall at any season. Each summer there are usually one or two storms in which "new snow" covers the mountains from timber line upward—quite the same phenomenon that is seen in the Alps. Aside from such storms and away from the immediate vicinity of the glaciers, nightly frosts are mostly light and irregular during July and the early part of August (light frost in the alpine meadows is often visible when the thermometer has failed to record freezing). After the middle of August the nights become notably cooler, the nightly frosts become sharper, and by the middle of September they are frequent at all altitudes.

PRECIPITATION.—The volume of precipitation appears to increase from the southeast to the northwest. In the terraced portion of the Columbia Valley, where there are a number of ranches, summer rainfall is so far from that desirable for crops that irrigation

[2] These records are unhappily lost.

will probably be necessary; and although the Selkirks and the Gold Range bear the reputation of being rain-soaked mountains, I suspect that sufficient information would place them in the summer-dry category.

My own data have been obtained in various places, and while on the march. Such items should be numerous and in long series in order to have much value, for showers are often of local occurrence and are more frequent in some localities than in others. A vivid impression of local differences is often conveyed from an outlook point where a wide expanse of peaks is visible. Over most of the landscape there may be sunshine, while Rogers Pass and the great peak in the north, variously called Cloud Summit, Sir Sanford,[3] and the Chieftain, are enveloped in dark rain clouds.

A rough summary of the weather in the growing season for a number of summers is given in table I.

The reputation which the Selkirks bear is probably due partly to the luxuriance of the vegetation, all the more striking to those who come from the thinly forested Rockies, and partly to the fact that very rainy summers have occurred. The accounts of the explorers who found the route for the railroad in the early eighties are tales of great hardship, in which tangled brush and incessant rain are prominent features. Witness also the memorable summer of 1907. So far as data are available, however, it would appear that summer precipitation is scanty, on the whole, and that the climate of the Selkirks resembles that of Puget Sound.

Whatever may be the fact in regard to rainfall, there is another form of precipitation, the regularity and abundance of which is not open to question. Light snows come and go about timber line occasionally during July and August, and more frequently during September and early October, until, by the first of November, the snow mantle is spreading rapidly downward into the forest. From November until the following spring, the whole surface of the earth is deeply covered. At Glacier, altitude 1260 m. as recorded by instrument, 75–150 cm. of snow falls annually. In the sub-alpine zone the packed snow becomes 2–3 m. deep, not to disappear until June; that at lower altitudes is somewhat less, the

[3] This name has since been adopted.

lightest occurring in the wide valley of the Columbia in the southeast. Such a layer of frozen water, annually renewed, slowly melting, setting free one portion of surface after another, and at the time

TABLE I

July and August	Number of days on which we met with rain	Comment
1904.....	11	Rains light, usually for a few hours only; in one case, at Rogers Pass, altitude 1300 m., clouds hung low, with nearly continuous drizzle for 4 days (August 21–26)
1905.....	9	Likewise mostly light rains and of short duration; one hail and two thunder storms at 2000 m. and one fall of about 20 cm. of snow August 5 at the same altitude
1906.....	.....	As stated by my brother, frequent showers but scarcely any heavy enough to cause one to seek shelter; two snows above timber line
1907.....	35	From August 3 to September 1 almost incessant rain, much of the time in copious volume; conditions general over the Selkirks, Rockies, and the Gold Range
1908.....	7	Only 3 or 4 short showers before August 25; most of the time uniformly fair; conditions general over the Selkirks, Rockies, and Gold Range
1909.....	13	Cloudy and rainy during early part of July but no copious precipitation; from July 18 to September 1 and after, prevailingly fair; a snowfall of about 35 cm. at timber line August 4 and 5, a *heavy* shower August 26
1910.....	4	A snowfall at timber line July 15; heavy rains July 21, 22, and 24; no other rains during July and early August

of its departure leaving the soil laden with all the water it can hold, must be, for vegetation, a most important factor in the physical environment.

Vegetation

The plant covering of the area exhibits, of course, a wide series of variations growing out of the specific nature of the forms, and out of differences in the surrounding physical factors. How best to study and describe such a vegetation complex is a puzzling matter. Following the broad distinctions of SCHIMPER, we may

designate three formations in the Selkirks: forest, alpine grassland, and alpine desert. The first two interlock, the latter two grade imperceptibly into each other. Within the forest are streams with their distinct plant life, and occasional areas of swamp and bog, as well as cliffs and gravel slides which exhibit desert conditions and to some extent the same species as the alpine deserts. Above the forest there is every gradation, from alpine rivulet to barren cliff. To attempt to reduce all this to a classified and logically complete system of subformations, societies, etc., is a task in which the writer can see neither profit nor hope. The interesting facts and relations which may be observed will be brought out simply as facts.

THE FOREST FORMATION.—The forest covers the entire area up to the timber line at about 1900 m. The most striking feature in its general physiognomy is the increase in luxuriance westward. In the Rockies and southeastern portion of the Selkirks the trees are usually not more than 30–50 cm. in diameter, and 15–25 m. high. In the Columbia Valley from Quartz Creek and the Beaver northward, however, and on all the western slopes of the Selkirks, the forests attain a magnificent development. The trees of various species are commonly 100–150 cm. in diameter and 30–60 m. high, suggesting, though by no means equaling, the marvelous forests of the Puget Sound region. It is scarcely to be doubted that this greater development is bound up with a greater precipitation over the area named. Related facts in regard to the peculiar distribution of certain species will be brought out later.

The forest is further diversified by the effects of fire. Fires have occurred apparently from remote periods, and all phases of succession can be found, culminating in the climax type. The chief cause of the fires seems to be lightning. A tree with a mass of dead resinous branches is a highly inflammable object, and, as a matter of experience, an outlook from a vantage point after a sharp thunderstorm usually reveals one or more slender columns of smoke rising from the forest. Fortunately such fires often die out before much damage is done.

With respect to altitude, the forest is rather plainly composed of two zones, which, in accordance with a usage now happily becoming somewhat uniform, we may designate as the montane

zone and the subalpine zone, the latter beginning at about 1400 m. We shall give attention to the former first.

The montane zone exhibits considerable diversity. The differences between the eastern and the western portions of the area are so strongly marked that the two might easily be treated separately. The hemlock occurs only in the northern and western portions. Quite a series of herbaceous plants (*Lycopodium lucidulum, Chimaphila umbellata, Corallorhiza Mertensiana, Asarum canadense, Circaea alpina*) have been found together only in company with the hemlock, and with it they might be said to constitute a distinct "society" or "formation." But, taking a broader view, we see that, since all these species are found in different combinations in various regions, the fact that they occur together under the hemlocks in the Selkirks indicates no more than that they each respectively sustain a living relation with the physical factors prevailing there. Doubtless the hemlock is very efficient in bringing about the moist and shady conditions in which the others commonly thrive, but further than this it is not apparent how expressions indicating a social interrelationship throw any light on the physiological problems involved. At this point also the interesting fact comes in that almost all the "shade" plants, the ferns excepted, have been found growing in the burns, largely exposed to sunlight.

The following are lists of the more conspicuous or noteworthy species of the montane zone arranged approximately in order of their abundance:

Trees

Principal species

Picea Engelmannii
Tsuga heterophylla
Thuja plicata
Pseudotsuga mucronata
Tsuga Mertensiana
Pinus monticola
Populus balsamifera

Minor species

Pinus Murrayana
Abies lasiocarpa
Populus tremuloides
Betula papyrifera
Acer glabrum

Shrubs

Alnus tenuifolia
Echinopanax horridum
Salix sp.
Vaccinium membranaceum
Rubus parviflora
Vaccinium ovalifolium
Lepargyrea canadensis
Pachystima Myrsinites
Lonicera ciliosa
Cornus stolonifera
Taxus brevifolia
Ribes echinatum
Ribes lacustre
Rubus strigosus
Spiraea betulaefolia
Corylus rostrata
Crataegus Douglasii (?)

Herbs (including all low forms)

Aspidium spinulosum dilatatum
Cornus canadensis
Kruhsea streptopoides
Vagnera amplexifolius
Rubus pedatus
Linnaea borealis
Tiarella unifoliata
Streptopus amplexifolius
Veratrum viride
Clintonia uniflora
Mitella nuda

Herbs (including all low forms)—*Continued*

Streptopus curvipes
Asplenium Filix-foemina
Phegopteris Dryopteris
Moneses uniflora
Pyrola secunda
Disporum majus
Pteridium aquilinum
Chimaphila umbellata
Fragaria glauca
Equisetum sylvaticum
Lycopodium lucidulum
Circaea alpina
Equisetum arvense
Equisetum pratense
Asarum canadense (acuminatum?)
Habenaria obtusa
Habenaria orbiculata
(Mosses and liverworts in abundance in the deeper forests)

A similar list of species found in an early phase of the reforestation of a burn will show the changes incident to fire:

Trees

Leading species

Tsuga heterophylla (2)
Pinus Murrayana (8)
Populus tremuloides (10)

Less prominent

Pseudotsuga mucronata
Picea Engelmannii
Pinus monticola
Thuja plicata
Betula papyrifera
Abies lasiocarpa
Populus balsamifera

Shrubs

Salix sp.
Lepargyrea canadensis
Pachystima Myrsinites
Rubus strigosus
Alnus tenuifolia
Vaccinium membranaceum
Rubus parviflora
Cornus stolonifera
Ceanothus ovatus
Amelanchier florida
Lonicera involucrata
Spiraea betulifolia
Ribes echinatum
Juniperus sibirica
Menziesia ferruginea
Viburnum pauciflorum

Herbs

Epilobium angustifolium
Linnaea borealis
Cornus canadensis
Apocynum androsaemifolium
Equisetum pratense
Pyrola secunda
Pteridium aquilinum
Vagnera amplexifolius
Clintonia uniflora
Pedicularis contorta
Pedicularis racemosa
Streptopus amplexifolius
Anaphalis subalpina
Chimaphila umbellata
Galium boreale

Poor specimens of
Phegopteris Dryopteris
Thalictrum occidentalis
Disporum majus

Picea Engelmannii is the most generally distributed species of the region. It occurs throughout the area, in the neighboring Rockies, and in the Gold Range, and extends upward into the subalpine. Its relative importance is greater in the southeast and in the Rockies, where it does not come into competition with the hemlock. In the southeast it is usually the most abundant species of the climax forest, although, like other trees in that quarter, mostly of 30–50 cm. diameter and a height of 15–25 m.

Tsuga heterophylla, on the other hand, is sharply limited in its distribution. It does not occur at all to my knowledge south or east of the Beaver and Columbia, being therefore quite absent from the Rockies. Within the bend, however, it at once becomes abundant and, growing luxuriantly as it does, may well be said to

dominate the vegetation in considerable areas; but it never entirely excludes the spruce, the mountain pine, and the Douglas fir. Within the area it is one of the most prominent trees of the burns, seeming in this respect like the lodgepole pine.

Thuja plicata is, at least in some respects, the monarch of plants in the Selkirks. Occurring sparsely in the Rockies and upper Columbia Valley, it finds its proper home in the deep moist valleys of the western arm of the Columbia. Here it not seldom reaches a diameter of 3 m. The trunk tapers rapidly, however, and is seldom over 50 m. high. Another fact which detracts from its timber value is that the trunks are usually decaye dwithin, a large and sound tree being almost unknown.

Pseudotsuga mucronata shows ability to endure and to respond to a wide variety of conditions. As is well known, it reaches a huge development in the Puget Sound country, forming perhaps the most magnificent forests on the globe. Nevertheless, it endures conditions of dryness better than most of the other conifers. It extends south to Colorado and beyond, and in Canada, as one passes from the treeless plain to the foothills, it is one of the first trees to appear. In the region we are studying it is nowhere abundant, yet it occurs throughout. It grows largest on the western slopes of the Selkirks, making there a diameter of 2 m. and a height of 65 m. or more.

Pinus monticola, a large white pine, is scattered through the area, nowhere very abundant, but becoming a valuable timber tree in the hemlock district.

Populus balsamifera occurs constantly along the river, sometimes forming forests several hundred meters wide. It reaches a diameter of 1–2.5 m. and a height of 30–45 m.

Pinus Murrayana, the lodgepole pine, is remarkable both for its limited distribution and for the part it plays in reforestation. In all the region where it occurs it is the first tree to spring up after a fire. In the Rockies particularly, the burn forest is often almost purely lodgepole pine. Its range is sharply confined to the Rockies and the drier portion of the Selkirks, ceasing rather abruptly where the hemlock begins. The cause of the peculiar distribution is not wholly clear. Possibly it cannot survive in

competition with the hemlock, and is confined therefore to areas where the latter cannot flourish on account of dryness. Possibly, also, the lodgepole pine has not been able as yet to cross the central mass of the Selkirks, nor to make its way from burn to burn around the bend. It certainly would have little chance to invade the climax forest.

Populus tremuloides is another prominent member of the burn vegetation, universally distributed, growing in company either with the lodgepole or the hemlock, as the case may be.

Abies lasiocarpa occurs sparingly in the montane forest. It is rarely to be seen near the river, but is one of the 3 or 4 species forming the tree clusters on exposed ridges.

The birches, maples, buckthorns, and hazels are found only along the river and the lower waters of its tributaries, and are usually not abundant.

In the moist river-level forests, especially along the western arm of the river, and in such moist pockets as that found at the foot of Mount Cheops at Rogers Pass, certain shrubs grow in remarkable luxuriance. Among these the most conspicuous are: in the river-level forests, *Echinopanax horridum*, *Taxus brevifolia*, *Corylus rostrata;* in the moist pockets, *Vaccinium ovalifolium*, *Rhododendron albiflorum*, alders, and willows. In the moist, well shaded river-level forests, especially along the Columbia between Bigmouth and the great angle made by the Columbia, vegetation reaches a marvelous degree of luxuriance. Here careful measurement indicated that the following spermatophytes and pteridophytes reached a height of 2.50–3 m.: *Veratrum viride*, *Echinopanax horridum*, *Vagnera amplexifolia*, *Pteridium aquilinum*, *Aspidium spinulosum dilatatum*. Here also the mosses *Hylocomium proliferum* and species of *Thuidium* covered the rocks and fallen tree trunks with thick cushions of exquisite foliage.

THE ALPINE MEADOW FORMATION.—As previously stated, the alpine meadow and the forest formations interlock, the former frequently extending far down below the timber belt in the depressions, while the latter reaches upward on the exposed mountain flanks and ridges. The bulk of the alpine meadow vegetation lies between 1800 and 2500 m. The plant associations vary greatly,

of course, according to altitude, topography, exposure, and moisture content of the soil.

Almost as important as altitude in determining the character of the vegetation of a given area are topography and exposure to light. While crags and ridges may be free from snow in May or early June, the depressions between them frequently lie buried under snow until the middle or latter part of July. These masses of wet snow are apparently responsible for the drowning and suffocation of the trees and larger shrubs in these depressions, as I suggested in an earlier paper.[4] Other things being equal, the snow disappears first from the east-facing and south-facing slopes; these slopes therefore usually bear a more luxuriant and more varied vegetation than those facing the west and north. It would seem that, in the Selkirks, long-enduring snow masses, caused by heavy winter precipitations, topography, and exposure of the mountain slopes, are the most important single factor in determining the distribution of the alpine meadow and alpine desert vegetation.

Among the trees which reach in scattered groups into the alpine meadows, thus forming true "parklands," firs and spruces predominate. At 1800 m., in the lower portions of the belt, these retain their characteristic conical form and frequently reach a height of 7 m. They are found most abundantly and are grouped most effectively on slight elevations surrounding the numerous alpine tarns of this newly glaciated country. At higher elevations, reaching even to 2500 m., the firs and spruces exhibit the forms of wind and snow cripples. Here they are associated with dense thickets of juniper, and with occasional groups of the white-stemmed pine (*Pinus albicaulis*). The thickets often cover the broader mountain flanks, the gnarled cripples appearing in smaller groups or singly on crags and narrow "sawbacks." An examination of the rings of wood in the trunks of some of these cripples gave evidence, as was to be expected, of extremely slow growth. Thus a fir, 40 cm. in height and 2.5 cm. in diameter of trunk, cut near the summit of Glacier Crest, between the Illicillewaet and Asulkan glaciers, showed 62 wood rings.

[4] SHAW, C. H., The causes of timber line on mountains. Plant World **12**: *figs. 4.* 1909.

Such shrubs as show any considerable length of stem commonly lie prostrate, thus giving evidence of the crushing effect of the masses of snow that cover the lower meadows during 9 or 10 months of each year. Of these *Rhododendron albiflorum* and *Vaccinium membranaceum* are most frequently met with on the lower slopes, especially on those threaded by rivulets originating in snow banks higher up. Farther up the slopes, and reaching quite to the alpine deserts, dwarf willows, *Arctostaphylos Uva-ursi*, *Cassiope Mertensiana*, *Empetrum nigrum*, *Bryanthus glanduliflorus*, *B. empetriformis*, *Gaultheria myrsinites*, *Kalmia glauca*, *Dryas octopetala*, and occasionally *D. Drummondii* are the dwarfed shrubs. These sometimes form small patches in the grassland; sometimes they form extensive carpets covering many square meters. Mats of *Cassiope* or of *Bryanthus* or *Dryas* form dry hummocks in comparatively wet meadows. As these mats enlarge year by year, the plants at the center die, thus bringing about the formation of rings of shrubby growth surrounding dead and blackened centers. This seems to bear out SCHROETER'S statement:[5] "Das dichte Heidekrautgestrüpp erzeugt einen ganz eigenartigen, schwarzen, nährstoffsarmen Humus, der eine Menge von Arten ausschliesst."

Moisture and the presence or absence of snow covering during the short growing season seem to be the principal factors determining the nature of the herbaceous vegetation of the alpine meadows. On very wet slopes and depressions, where the ground is continually soaked by water from the melting of the snow fields higher up, there are commonly either nearly pure stands or mixed associations of the following: *Ranunculus alpinus*, *Trollius albiflorus*, *Caltha Macounii*, *Lutkea pectinata*, *Valeriana Scouleri*, and *Erythronium grandiflorum*. With these are associated, in lesser quantities, *Mitella nuda*, *Petasites frigida*, *Oxyria digyna*, *Rumex crispus*, *R. acetosella*, *Parnassia parviflora*, *P. fimbriata*, *Saxifraga rivularis*, *S. Lyallii*, *S. nivalis*, *Thalictrum occidentale*, *Epilobium angustifolium;* numerous sedges and grasses, among them *Carex invisa*, *C. nigricans*, *C. livida*, *Poa arctica*, and *P. alpina*. The stretches of *Erythronium* and of *Trollius*, varied by very intruding plants of

[5] SCHROETER, C., Das Pflanzenleben der Alpen.

other species, are especially beautiful and interesting. Occasionally one comes upon fields, several acres in extent, consisting apparently of nothing but the swaying yellow bells of *Erythronium*. Some of the smaller basins, where the snows have but recently melted, are entirely filled with *Ranunculus alpinus*, which often blooms under the shallow snow water. Of the principal species, *Trollius*, *Valeriana*, and *Erythronium* are commonly found together; while *Lutkea*, *Ranunculus*, and *Caltha* form another and quite distinct association. As the slopes become drier, cushion plants of various species may be associated with these plants. Of these the most abundant are *Silene acaulis*, the two species of *Dryas*, the saxifrages, the heathers, sedges, and grasses.

On the mesophytic grasslands, *Pulsatilla occidentalis* is the dominant plant. Large fields and gentle slopes covering hundreds of square meters often bear *Pulsatilla* to the exclusion of all other vegetation. Where this condition obtains, its chief cause is always in evidence, namely, scores of burrows of the ground squirrels that delight to line their homes with the plumed fruits of the *Pulsatilla*, thus assuring the reproduction of the plant. When *Pulsatilla* does not form a pure stand, it is most frequently associated with several alpine grasses, *Poa alpina*, *P. arctica*, *P. Cusickii*, *Phleum alpinum*, with *Juncoides parviflora*, *Carex festiva*, and *C. marcida;* and with *Castilleia miniata* and *C. pallida* (running into numerous variations in color and form), *Lupinus perennis*, *Valeriana sitchensis*, *Erigeron jucundus*, *E. salsuginosus*, *Epilobium Hornemanni*, *E. anagallidifolium;* as well as with occasional clumps of heather (*Bryanthus* and *Cassiope*) and of dwarf willows. These plants commonly grow in remarkable luxuriance, and in August, when most of them are in bloom, the brilliant colors of species of *Castilleia*, *Erigeron*, *Epilobium*, and *Lupinus* give to the alpine fields a beauty not readily forgotten by anyone who has had the good fortune to see it.

On the gravel slopes and flats of the youngest terminal moraines a great variety of physical conditions obtains. As to moisture, the range is from wet areas where the glacial streams form pools or bogs, to the sun-baked flats no longer reached by these streams. Here the soil appears at the surface, there it is covered by gravel

and boulders to a depth of a meter or more. Exposure to light is almost invariably extreme. Many of the gravel slopes and flats come properly within the alpine meadow zone. Their vegetation varies, of course, with the physical conditions under which it must exist. The xerophytes grow always in isolated clumps or cushions; the hydrophytes and mesophytes either in clumps or in fairly extensive beds. The xerophytes most in evidence are: *Erigeron aureus*, *Antennaria lanata*, *Kalmia glauca*, *Arnica latifolia*, *Epilobium angustifolium*, *Potentilla emarginata*, *Gentiana prostrata*, *Dryas octopetala*, *D. Drummondii*, *Eriophorum polystichium*, *Calamagrostis purpurascens*, and *Cryptogramma acrostichoides*. A number of these species are found also on the alpine desert. This does not seem remarkable if one considers that, except for increased cold and snow, the conditions under which the desert plants exist are similar to those endured by the morainal xerophytes.

The hydrophytes and hydromesophytes of the moraines are numerous. They often form dense masses of vegetation along the streams, especially on the more level flats. The species found, named approximately in order of abundance, are as follows: *Trollius albiflorus*, *Claytonia lanceolata*, *C. parviflora*, *Rumex crispus*, *Oxyria digyna*, *Caltha Macounii*, *Ranunculus Eschscholtzii*, *Petasites frigida*, *Thalictrum occidentale*, *Parnassia fimbriata*, *Carex nigricans*, *Veronica Wormskjoldii*, *Castilleia miniata*, *Mimulus Lewisii*, *M. caespitosus*, *Epilobium latifolium*, *Eriogynia pectinata*, *Leptarrhena amplexifolia*, *Saxifraga Lyallii*, *S. rivularis*, *S. Nutkana*, *Tiarella unifoliata*, *Aquilegia columbiana*, *A. flavescens*, *Silene acaulis*, *Delphinium Menziesii*, *Anemone Drummondii*, *Parnassia parviflora*, *Erythronium grandiflorum*, *Veronica americana*, *Pedicularis bracteosa*, *P. racemosa*, *Pinguicula vulgaris*, *Epilobium Hornemanni*, *Erigeron jucundus*, *E. multiradiatus*, *E. salsuginosus*, *Comarum palustre*, *Myosotis alpestris*, *Cynoglossum boreale*, *Apocynum androsaemifolium*, *Gentiana glauca*, *Gaultheria humifusa*, *Ligusticum apiifolium*, *Valeriana sitchensis*, *Aster conspicuus*, *Habenaria hyperborea*, *Senecio triangularis*, *Veratrum pedicularis*, *Rhododendron albiflorus*, *Kalmia glauca*, *Elephantella groenlandica*, *Potentilla emarginata*, *Prunella vulgaris*, and *Sibbaldia procumbens*.

THE ALPINE DESERT.—Here low temperatures, snow, and the avalanches due to these are evidently the controlling ecological factors. It is necessary to distinguish between the deserts due to cold and snow, and those due to rock avalanches. The latter are either absolute deserts because recurring avalanches have covered the soil of the slopes with rock to such a depth that vegetation is impossible, or they show isolated plants or cushions of plants where rock covering chances to be shallow. These comprise very few species, *Gentiana prostrata*, *Erigeron aureus*, *Silene acaulis*, *Potentilla* (*emarginata?*), *Epilobium latifolium*, and *Cryptogramma acrostichoides* being the only species found very commonly in these locations. All of these rock desert plants are, of course, extremely small, tough, and dry; their blossoms often impress one as being of unusual size and brilliancy in contrast with the dwarfed and dull green foliage and stems. Since these plants secure moisture only with difficulty, and endure the strong insolation and the desiccating winds of the exposed rock slides, they are to be designated without question as xerophytes, a designation usually supported by such structural characteristics as have just been suggested.

The snow and cold deserts of the high altitudes are peculiarly interesting. At the surface and immediately beneath the surface of the snow, especially on the more extensive snow fields, many thousands of plants of *Sphaerella nivalis* give to the snow exquisite rose and lavender tints. In the Selkirks the alga never has the green color which SCHROETER reports that it shows on the alpine snows. With *Sphaerella* there is frequently associated a fungus which spreads its dark brown, branched mycelium over the surface of the snow. Except for these two plants, the Selkirk snows seem to be truly bare of plant life.

On those high slopes where snow patches remain practically throughout the summer, and where the ground between the patches is free of snow during a few weeks only, a very definite succession is always to be discerned. Very near the snow, surrounding the melting snow patches, there is a black mud with knobby surface evidently covered with fungus mycelia; farther back from the edge of the snow, tiny patches of *Polytrichum* appear. As the clumps of moss increase in size, we find it associated with small bunches

of *Carex nigricans*, which increase in size as we recede from the snow until they form a continuous ground covering. Thus far the succession is invariable; but the plants that grow in scattered groups in the stretches of *Carex nigricans* at some distance from the snow patches may be *Carex invisa*, *Epilobium latifolium*, *Petasites frigida*, *Caltha Macounii*, *Oxyria digyna*, *Parnassia parviflora*, or a *Ranunculus*. When one or more of these plants have joined *Carex nigricans*, conditions no longer warrant the designation of "desert" to this association, but it merges into the hydrophytic or hydromesophytic group, for moisture from the melting snow patches is, of course, abundant in these situations. The term "desert" as applied to the fungus-moss-sedge association bears with it none of the usual suggestions of dryness and heat, but, on the contrary, connotes abundant moisture but physiological dryness due to extreme cold. It is to be remembered in this connection that the suffocating action of the snow, previously mentioned, is here a potent cause of the poverty of plant life.